Armenian Journal of Physics, 2018, vol. 11, issue 4, pp. 231-234

Power Analog of Trigger Schmitt's

(Proceedings of the Int. Conference on " Microwave and THz Technologies and Wireless comm.")

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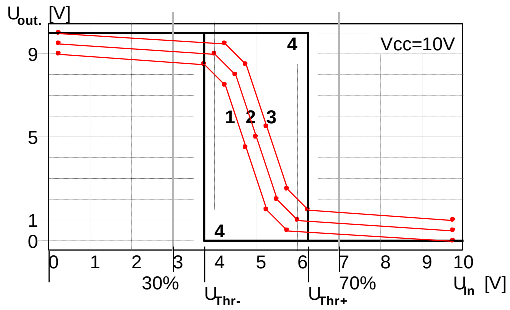
Received 15 November 2018

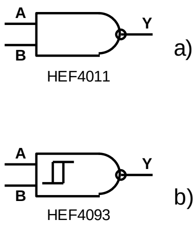
Abstract: Our designed electrical appliance is intended for use in managing and controlling devices as a powerful electrical coupling hub. It is a functional equivalent of the HEF4093 integrated circuit and is assembled on the basis of a modern integrated circuit (comparator) and a MOSFET transistor for power output. The input of the scheme requires digital or analog signal. At the output of the device it is possible to switch the load, which may have high currents. The transistor is protected from the short load mode. The structure of scheme allows the free choice of comparator and transistor based on the required electrical parameters. The device model has been tested on 0.5-2 amperes range.

Keywords: Schmitt's trigger, integrated circuit, logical function elements.

1. Introduction

It is known that all types of digital circuits are based on series of logical function elements: "AND", "NOT", "OR", "NAND", "NOR". The characteristics of the "input-output" dependence of the "NAND", "NOR" elements are shown in Fig. 1 where curves 1, 2, 3 are indicating possible deviations from the average position.





Functional Table		
$Y=\overline{AxB}$		
Inputs		Output
A	B	Y
L	L	H
L	H	H
H	L	H
H	H	L
H=High Logic Level		
L=Low Logic Level		

Fig. 1. **Fig. 2.** **Fig.3.**

The signal corresponding to the logic level "0" should be no more than 30% of the supply voltage (V_{CC}) to avoid an undefined zone in the center of the characteristic, and the signal corresponding to "1" should be at least 70%. The HEF4011 microcircuit contains 4 elements "2xNAND" and input characteristics have indicated by numbers 1, 2, 3 in Fig.1. [1].

It is also known that logical signals, which are supplied to the input of simple logic circuits, must have very short fronts in time (about $1...20ns$) to ensure low consumption currents. If it is necessary to feed signals of the inputs of logic circuits with more rise and fall times with the orders of μs or ms and reduce the current consumption and 40% range of uncertainty, logic elements with a Schmitt trigger circuit at the inputs (for example, HEF4093) are used. The trigger provides the hysteresis characteristic shown in Fig.1 (curve 4), where the transition from "0" to "1" and from "1" to "0" is about 20% of V_{CC}. The symbol of the element "2xNAND" of the usual scheme is shown in Fig. 2a and the symbol based on the Schmitt trigger is on Fig. 2b. They have the same logical table of functions, as shown in Fig.3. [1, 2].

The advantage of the Schmitt trigger circuit is that we can give to its input not only digital signal, but also an analogue signal and the internal transistors are always either in the saturation or in the cut-off modes and the chip consumes very little power.

The disadvantage of the digital element as an analog converter with the input of the Schmitt trigger is that it requires a high input signal $(0.6V_{CC} \div 1V_{CC})$. Usually the supply voltage will be from $3V$ to $15V$ for such microcircuits. Therefore, using the simplest digital circuit, it can convert an analog signal, the smallest value of which can be $U_{in} = 0.6 \times 3V = 1.8V$.

2. Objective

The purpose of the work is to develop the analog of HEF4093 that performs the function “2xNAND”, with sensitivity of the order of mV and has an output operating current tens or hundreds of times more than the chip HEF4093.

Analog signals (starting from mV) can be converted to digital without prior amplification, using an integrated comparator, the symbol of which is shown in Fig.5. [3]. Such signals are obtained from various analog transducers of physical values into an electrical signal.

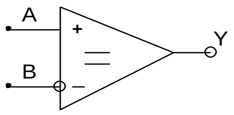


Fig.4.

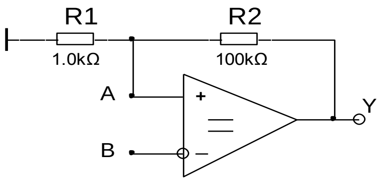


Fig.5.

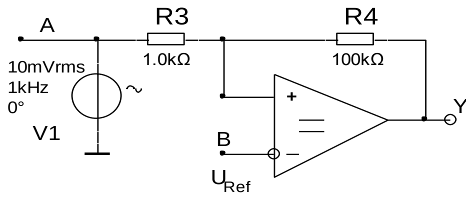


Fig.6.

The comparator function is described as follows: if $U_a - U_b = \Delta U_{in} > 0$ (on the order of mV), then $Y = "1"$ and if $U_a - U_b = \Delta U_{in} < 0,$ then $Y = "0"$. Therefore the moment of equality of two signals can be represented by a logical $"0"$ or $"1"$ with accuracy of the order of mVs. The biggest advantage of the Schmitt trigger based on the comparator is that it can send analog signals to its input, ranging from mVs to the supply voltage.

In Fig.5 is shown a comparator with positive feedback, performed on the R1 and R2 resistances. Due to positive feedback, a hysteresis is automatically generated. The upper threshold of the comparator is determined from the equation $U_{Thr+} = U_{out} \times R1/(R1+R2)$, where $U_{out} = V_{CC}$. Accordingly, the lower threshold is $U_{Thr-} = U_{out} \times R1/(R1+R2)$, where $U_{out} = 0$, or $U_{out} = V_{EE}$. The hysteresis voltage is defined by $U_{Hist} = U_{Thr+} + U_{Thr-}$.

Based on the requirements of the task, it can choose any voltage and width of the hysteresis and calculate the resistances $R1, R2$. In terms of application, this Schmitt trigger based on the comparator is very flexible. If in the Fig. 5 the left end of resistance $R1$ is used as an input and a variable signal is fed there and the input of B is for voltage U_{REF}, then the moments when the input voltage A exceeds the reference voltage can be registered with hysteresis accuracy (Fig.6) [3].

On the basis of Fig.6, was developed a “2xNAND” circuit for analog signals (Fig.7), where a high-power N-channel field-effect transistor (FET) is used as an inverter [4].

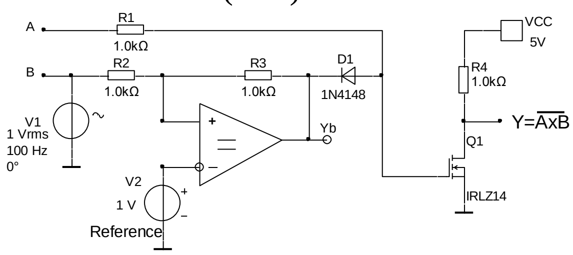


Fig.7.

Input A in the Fig.7 is intended only for a logical signal, and input B for any logical or analog signals. If necessary, it can select the desired reference voltage U_{REF}. This circuit is equivalent to a HEF4093 chip with more flexible inputs and a powerful output.

When $U_A = "1"$ and $U_B > U_{REF} + U_{Hist}$, then the output of the circuit is $Y = "0"$ (transistor Q_1 is in saturation mode). The current which pass through the load $R4$ is determined by the following equation: $I_{Load} = V_{CC}/(R4 + R_{sat})$, where R_{sat} is the internal resistance of Q_1 when it is in saturation mode. It can provide current from hundreds of mAs to several amperes by choosing the necessary transistor Q_1.

It was designed a powerful analogue of the Schmitt trigger based on the scheme of the Fig.7 in order for using in the security and management schemes. For this purpose, the circuit in Fig.7 was supplemented with a circuit which limits the load of current on a security level. The circuit is shown in Fig.8 with a current stabilization.

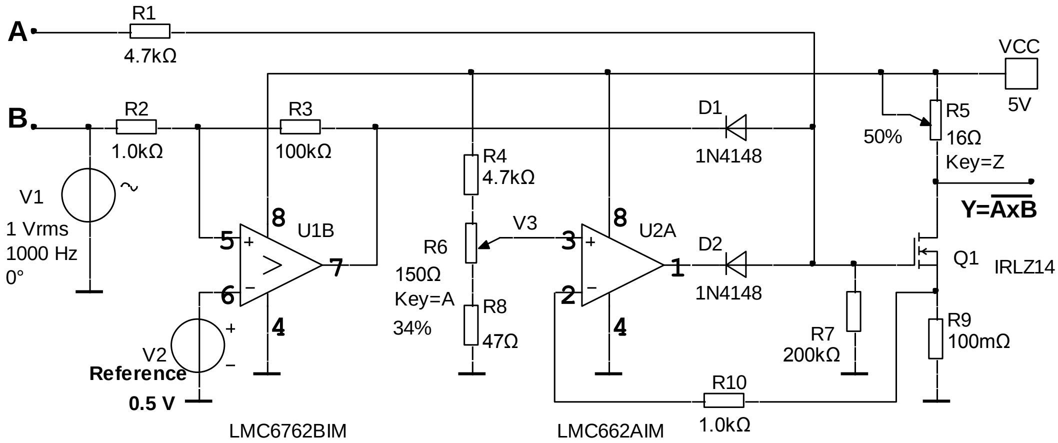


Fig. 8.

In this circuit, the resistances $R5$, R_{sat} and $R9$ pass the same current. The load current I_{Load} is determined by the following equation: $I_{Load} = V_{CC}/(R5 + R_{sat} + R9)$. If $R5$ is much greater than R_{sat} and $R9$, then $I_{Load} = V_{CC}/R5$.

In Fig.8, the circuit elements $R1, R2, R3, V2$ and $U1$ constitute the function of comparator part of the circuit [5]. The elements $R4, R6, R8, R10, D2$, operational amplifier $U2$, FET transistor Q_1 and $R9$ constitute a current stabilizer [6]. The stabilization current of the transistor is determined by the equation $I_{sat} = V_3/R9$ [3].

3. Experiment

The model uses a powerful FET N-channel transistor IRLZ14S with parameters: allowable drain voltage $60V$, direct drain current $10A$, resistance in saturation mode $0.2\Omega, TO-220$ package, power dissipation $43W$.

The stabilization current is regulated by a resistor $R6$ within 0.5-2A (V3 = 50 ... 200mV).

The table shows the results of the experiment at V3=100mV.

Table

R5 [Ω]	16	12,8	11,2	9,6	8	6,4	4,8	3,2	0	0
$I_{sat}[mA]$	308	342	384	437	508	754	992	1030	1030	1030

The table shows that the current stabilizes at a level of $1A$ with $R5 \leq 4.8\Omega$ and the circuit is protected from short circuit. The power dissipated on the transistor will be $P_{Q_1} = V_{CC} \times I_{sat} = 5W \ll 43W$.

Required designs of radiator, dissipation area for the $TO-220$ package easily provide the heat sink of the transistor Q_1 .

4. Conclusion

1. It was developed a powerful and full functional analogue of the HEF4093 chip with sensitivity of the order of *mVs* and has an operating output current from hundreds of milliamperes to several amperes.
2. It was given an example of implementation, where the resistance $R9$ and the output transistor work even in the short circuit mode, due to the small power dissipation on them.
3. This circuit design ensures continuous and uninterrupted operation of security devices, where short circuits of supply wires of remote loads often occur.
4. The power dissipated at the commutation transistor is many times smaller than the permissible power dissipation of it after entering the current stabilization mode.

References

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